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The influence of crown-to-implant ratio on marginal bone levels around splinted short dental implants: A radiological and clincial short term analysis

Hingsammer, Lukas ; Watzek, Georg ; Pommer, Bernhard

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ORIGINAL ARTICLE

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The influence of crown-to-implant ratio on marginal bone levels around splinted short dental implants: A radiological and clincial short term analysis

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Abstract

Background: The amount of marginal bone resorption around dental implants is considered to have a significant impact on implant stability as well as implant survival rates.

Purpose: The aim of this prospective study was to investigate the influence of prosthetic as well as patient specific factors on marginal bone loss around short dental implants.

Materials and methods: Seventy-six implants, which supported splinted crowns were included for investigation. All implants were from the same type and had an intraosseous length of 6.5 mm and a diameter of 4.0 mm. Twenty implants were additionally splinted onto longer ones. Measurements of marginal bone loss were performed at a mean of 12.38 months after prosthetic loading and the mean follow-up for clinical evaluation was 20.52 months.

Results: Overall two implant failures were recorded, revealing a survival rate of 97.3%. Marginal bone resorption around 72 short implants measured 0.71 mm (SD: 0.74 mm) and was found to have a strong correlation with calculated Crown-to-Implant ratio ($r = .71$; $P < .001$). Age, gender, insertion torque, implant surface area, location, position, bone quality, and insertion torque did not influence peri-implant bone loss after one year of loading.

Conclusion: Within the limitations of the study, it is suggested that Crown-to-Implant ratios should not exceed 1.7 to avoid increased early marginal bone loss.

KEYWORDS

crestal bone resorption, implant survival, prospective, short implants

1 | INTRODUCTION

During the past decades, implant therapy constitutes a successful option for tooth replacement. However, poor bone quality and even more bone quantity make their use considerably more difficult.[1,2] After tooth loss, however, severely atrophic residual alveolar ridges are quite common, especially in patients who have been edentulous for a long period of time.[3] Atrophic posterior regions frequently represent a challenge for implant therapy, making invasive augmentation procedure necessary.[4–6] Although widely utilized, these techniques imply greater morbidity, longer treatment times, and higher costs.[7–9] Sinus cavity in the maxilla and alveolar nerve proximity in the mandible are clinical situations where short implants may be considered as an alternative or even more favorable treatment option.[9–12] In the long term, implants of <10 mm are reported to be as predictable as longer implants.[13] Based on finite element analyses implant length only plays a minor role when considering stress concentrations operating on the implant bone interface.[14–16] Instead implant diameter is suggested to be a more effective design parameter to avoid an overload of peri-implant bone.[17,18] Maximal principal stress concentrations during occlusal load are identified to be located around the crestal part of the implant regardless of implant length or diameter.[14,19] However, implant design parameters have clear interactive effects, and therefore, they should always be considered together.[20] Beside occlusal overload, nonaxial loading, surgical trauma and incorrect implant position, subcrestal implant insertion has been reported to influence early marginal bone loss around dental implants.[21–23] The magnitude of marginal bone loss (MBL) is stated to be an essential indicator for implant stability and long-term survival rates,[21–23] whereby the highest rate of peri-implant bone loss is observed during the first year of implant loading.[21,24,25] Regarding biomechanical characteristics, high crown-to-implant ratios (CIR) are reported to have an unfavorable influence, resulting in increased MBL.[15,26] Thus, the resulting alteration of the clinical CIR is associated with even more tensions on the most cervical peri-implant bone.[27]

In consequence, as with the use of short dental implants, the establishment of high Crown-to-Implant ratios (>1.5) is often unavoidable, their indication has to be considered critical from this point of view.

Beside the clinical outcome the aim of this study is to determine the influence of the CIR and other patient- and prosthetic-related parameters on early MBL around short dental implants.

2 | MATERIALS AND METHODS

The study was performed prospectively and approval of the local ethics committee was given. Consequently, the study was conducted in accordance with the fundamental principles of the Helsinki Declaration, concerning research on human subjects.

Recruitment of patients followed predefined inclusion and exclusion criteria. Inclusion criteria were defined as[1]: partial edentulous in the posterior region[2]; enough residual bone to allow implant placement of 6.5 x 4.0 mm implants without augmentation procedures.[3] opposing dentition[4] free from caries and active periodontitis[5] patients in good general health; class I or II according to the American society of anesthesiologists (ASA)[6]; ≥18 years of age and willing to participate for the duration of the study[7] able to provide informed consent.

The following exclusion criteria were applied[1]: patients with substantive functional limitations regarding ASA class III or higher[2] pharmacologically treated osteoporosis[3]; history of irradiation[4]; insufficient bone quantity to allow implant placement[5] previous implant and/or graft installation at the site of implant placement[6]; inadequate oral hygiene.

3 | SURGICAL PROCEDURE

Surgical procedures and prosthetic restoration were carried out at the Dental University of Vienna in the years 2009–2013. All investigated short implants were from the same type (NobelSpeedy Groovy Shorty, regular platform, Nobel Biocare, Göteborg, Sweden) with an intraosseous length of 6.5 mm and a diameter of 4.0 mm. All implants had TiUnite surfaces and machined necks. Surgical implant placement followed the standardized protocol of the manufacturer using an INTRAsurg 1000 surgical unit (KaVo, Bieberach, Germany) to measure peak insertion torques. Implants were inserted either subcrestal or supracrestal, depending on the anatomical situation According to the guidelines of the Dental University of Vienna the subgingival healing period of the implants was 4–6 weeks. Antibiotics either amoxicillin 875 and 125 mg clavulanic acid or clindamycin 300 mg were prescribed and taken before and after implant placement. No provisionalization was used. All prosthetic restorations, were fixed with screws onto the implants. In all patients, implants supported splinted crowns. In 11 cases, implant restorations were additionally splinted onto longer implants (NobelSpeedy Replace 10 x 3.5 mm or NobelSpeedy Replace 13 x 3.5 mm). All implants featured an external hex connection type. Regarding the University's recall system patients were frequently subjected to clinical examinations. Within clinical examinations peri-implant abnormalities, increased probing depth (>4 mm), impaired wound healing and any problems with prosthetic restorations were recorded. Assessment of radiological images identifying MBL was carried out at two-time points. First directly after the prosthetic restoration was fixed and second at 12 months of follow up. Measurements of marginal bone loss were performed after the correction of any magnification failures on 2D intra-oral periapical radiographs using Sidexis software (Sirona Dental Systems, Bensheim, Germany).[28,29] Values of the specific implant surface areas (ISA), type, and dimensions of used implants are listed in Table 1. To detect inter and intraexaminer variability all images were analyzed twice by two independent examiners. Clinical CIR was calculated according to the conventional radiological method.[21,30] The clinical CIR was determined at baseline and defined as the relationship between crown height space and clinical implant length.[21,30]

TABLE 1 Type, dimension, and surface area of used implants

Implant type	Dimension (mm)	Surface area (mm^2)
NobelSpeedy groovy shorty	6.5 × 4.0	64.58
NobelSpeedy replace	10.0 × 3.5	114.99
NobelSpeedy replace	13.0 × 3.5	145.78

4 | STATISTICAL METHODS

Graph Pad Prism 6.0 software (Graph Pad Software Inc., California) was used for statistical analysis. Data were described as mean ± SD. The measured values of marginal bone loss within predefined groups were evaluated for statistical significant differences using the unpaired nonparametric Mann-Whitney *U* test. Multiple regression analysis was used to detect interparametric influences. The nonparametric Spearman correlation test was conducted to determine the correlation coefficient (*r*) and the *P* value for non-normal distributed, non-linear values. For normal distributed values with a linear coherence Pearson's correlation test was used. Kolmogorov-Smirnov test served to check if values are normal distributed. Correlation coefficients were interpreted as 0.8 to 1.0 or −0.8 to −1.0 (very strong relationship), 0.6 to 0.8 (strong relationship), 0.4 to 0.6 (moderate relationship), 0.2 to 0.4 (weak relationship), and 0.0 to 0.2 (weak or no relationship). Kappa statistic was

TABLE 2 Distribution of implants according to the region of insertion

Maxillary region	18	17	16	15	14	24	25	26	27	28
N = 29	0	6	6	3	0	2	3	5	3	1
Mandibular region	48	47	46	45	44	34	35	36	37	38
N = 45	0	7	9	5	3	1	5	10	5	0

used to test interexaminer and intraexaminer variability of measured marginal bone loss values and CIRs. Bland-Altman graphs served to illustrate interrater agreement. *P* values were considered as significant if $\leq$.05.

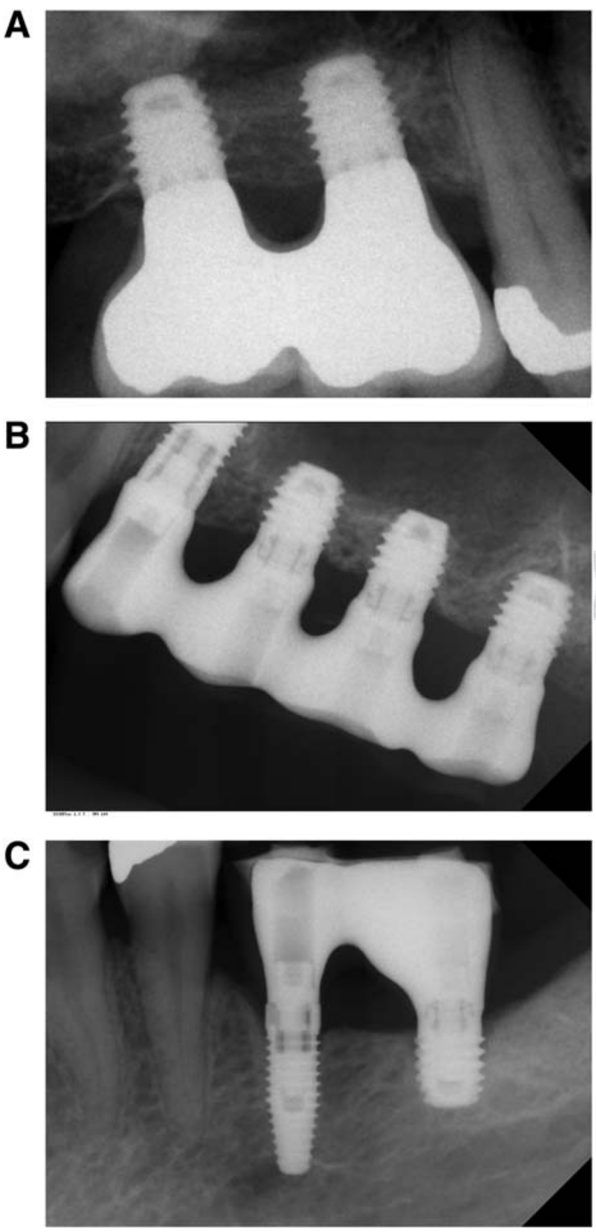

FIGURE 1 Radiographs showing various situations after 1 year of loading. A, Two splinted short implants in the maxilla. B, Three short implants splinted onto one longer implant in the maxilla. C, One short implant splinted onto on longer implant in the mandibular region

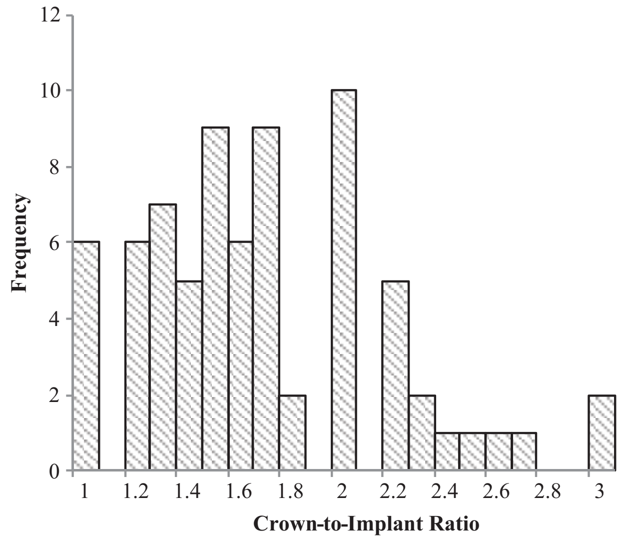

FIGURE 2 Histogramm showing the frequency of CIR

5 | RESULTS

Out of the 30 patients and 76 implants one patient, provided with two implants, had to be excluded due to an acute heart attack 7 months after implant loading, not allowing further appointments. During the mean clinical follow-up of 20.52 months (SD: 6.2; range 13.2–36.0) two implants (in one patient) out of 74 failed due to implant loosening 2 months following implant insertion in the posterior mandibular region. Thus, revealing an overall clinical survival rate of 97.3%. Table 2 gives an overview of the implant distribution.

Clinical examination, except for the failed implants, did not reveal any wound healing problems nor any increased probing depths (>4 mm). One patient needed a new prosthetic restoration after 29 months of loading. Radiolographic evaluation of 72 implants in 28 patients was performed 12.38 months (SD: 0.65; range 12–14 months) after prosthetic loading. Figure 1. shows three radiographs of some restorations after one year of loading. Patient age ranged from 27 to 78 years with a mean of 52 ± 11.9 years. All implants were placed in the posterior (premolar/molar) region of either the upper or lower jaw. Forthy-five (63%) implants were placed in the mandible and 27 (37%) in the maxilla. All implants supported splinted crowns and had machined neck surfaces. In three cases, implants with a dimension of

TABLE 3 Univariate analysis of correlations between MBR and relevant numerical parameters

MBR versus	*r*	*P*
Age	−0.16	0.183
Insertion torque	0.42	0.0002*
Insertion depth	0.35	0.041*
CIR overall	0.71	<0.00001*
CIR (mandible)	0.73	<0.00001*
CIR (maxilla)	0.36	0.072

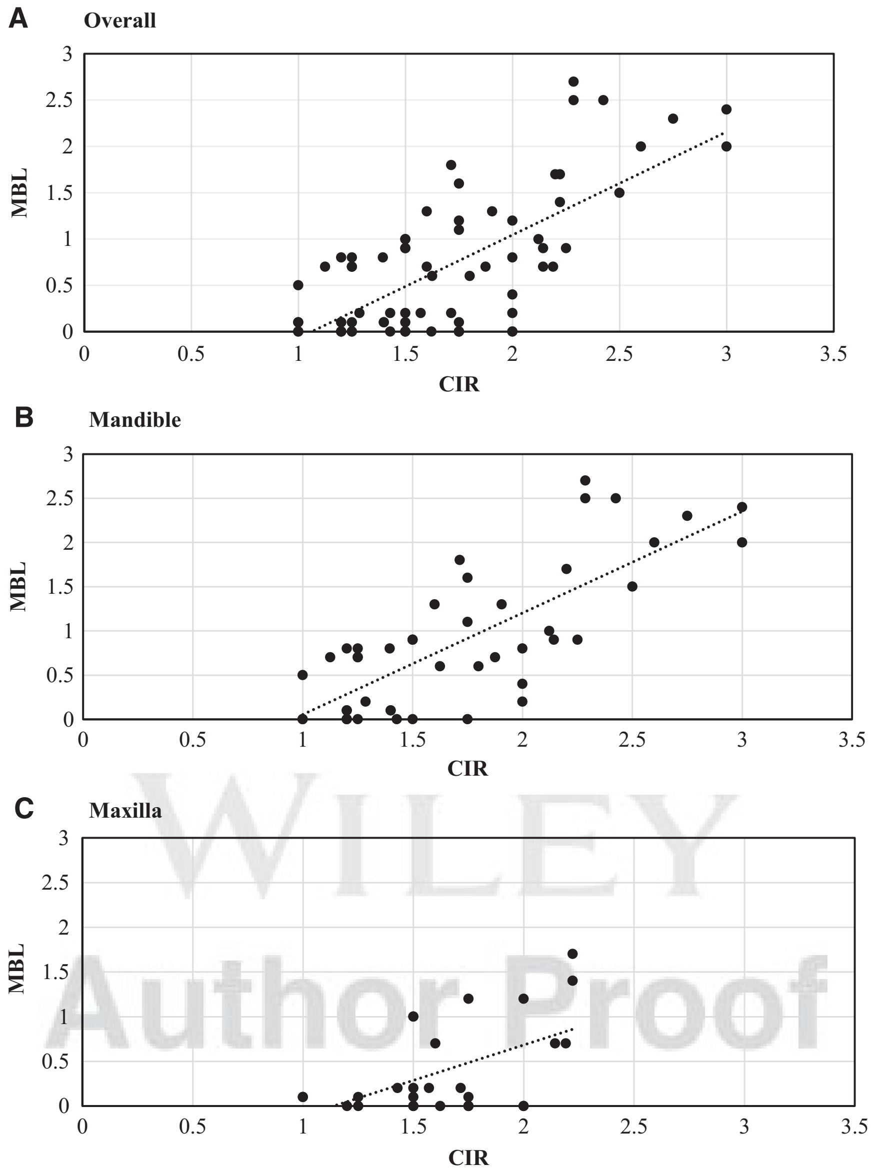

FIGURE 3 A, Overall correlation of MBL and CIR. Dashed line indicating linear correlation ($r = .71$; $P < .001$, $n = 72$). B, Correlation of MBL and CIR of maxillary implants. Dashed line indicating linear correlation ($r = .36$; $P = .068$, $n = 27$). C, Correlation of MBL and CIR of mandibular implants. Dashed line indicating linear correlation ($r = .73$; $P < .001$, $n = 45$)

10 x 3.5 mm and in eight situations 13 x 3.5 mm implants additionally supported the restoration as they were splinted to the short implants. Overall, 20 short implants were splinted onto longer ones, the rest (52 implants) were splinted onto other short ones. No implant supported a single crown. The mean radiological measured CIR was 1.70 (SD: 0.48, $n = 72$). CIR was higher in the mandible (mean: 1.75, SD: 0.08, $n = 45$) compared to the maxilla (mean: 1.61, SD: 0.06, $n = 27$). In Figure 2, the frequency of CIR values is outlined.

The mean crown height space was 9.9 mm (SD: 1.24 mm; range: 8.1–12.4 mm). About 25% of patients ($n = 8$) were identified as smokers, 17.8% ($n = 5$) had a history of periodontitis, and 10.7% ($n = 3$) presented bruxism habits. Implant insertion depth ranged from 1 mm supracrestal to −2 mm subcrestal, resulting in a mean of 0.66 mm (SD: 0.84). The torque of implant insertion varied from 15 to 50 Ncm (mean: 36.2 Ncm; SD: 9.2).

In Table 3, the correlation of mean peri-implant loss and different implant, prosthetic, or patient characteristics (age, location, insertion torque, insertion depth, and Crown-to-Implant ratio) is illustrated. Mean peri-implant bone loss measured 0.71 mm (SD: 0.74 mm) and was found to have a strong correlation with calculated overall CIR ($r = .71$; $P < .00001$) and mandibular CIR ($r = .73$; $P < .00001$). Moderate correlation with maxillary CIR ($r = .36$) was calculated (Figure 3). MBL of mandibular implants was 0.91 (SD: 0.56 mm) and that of maxillary implants was 0.38 (SD: 0.46 mm), showing a statistical significant difference ($P = .008$). Mean MBL of the 52 implants that have not been splinted onto longer ones measured 0.64 mm (SD: 0.74 mm). Sixteen of the 20 implants splinted onto longer ones were inserted in the mandible and revealed a mean MBL of 0.90 mm (SD: 0.71 mm). No significant difference between groups exist ($P = .071$). Mean MBL values of different groups and a descriptive subgroup analysis according to patient-, implant-, and prosthetic-related factors (gender, age, location (maxilla/mandible), position (molar/premolar), insertion torque, insertion depth, bone quality, implant surface area, CIR, type of splinting) is given in Figure 4. In Table 4, subgroups were tested on significance.

The insertion torque revealed to have a moderate ($r = .42$; $P = .0002$) and insertion depth ($r = .35$; $P = .041$) as well as maxillary CIR values a weak ($r = .36$; $P = .072$) relation to MBL. Whereas no relation to age could be detected ($r = -.16$; $P = .183$).

Multiple regression analysis revealed no influence of crown height space ($P = .279$), implant surface area ($P = .384$), age ($P = .594$, gender ($P = .204$), smoking ($P = .066$), periodontitis ($P = .026$) bruxism ($P = .687$) insertion depth ($P = .089$), insertion torque ($P = .314$), position (molar or premolar; $P = .425$), location (maxilla or mandible; $P = .109$) and bone quality ($P = .351$), and on MBL. However, CIR has been detected to have a statistical significant influence on peri-implant bone resorption: Around restorations with higher CIR increased bone resorption was measured ($P < .001$).

Interrater reliability yielded an overall kappa of 0.81 (93% of agreement) and 0.73 (89% of agreement) for CIR and MBL measurements, respectively. Intrarater agreement was 91% ($\kappa = 0.80$) for CIR values and 87% ($\kappa = 0.74$). In Figure 5, Bland-Altman plots show mean differences and 95% predictions intervals of interrater agreement.

6 | DISCUSSION

Peri-implant MBL plays a key role for long-term implant stability.[25,31] According to the established success criteria MBL should not exceed 1.5 mm after the first year of loading and not 0.2 mm in the

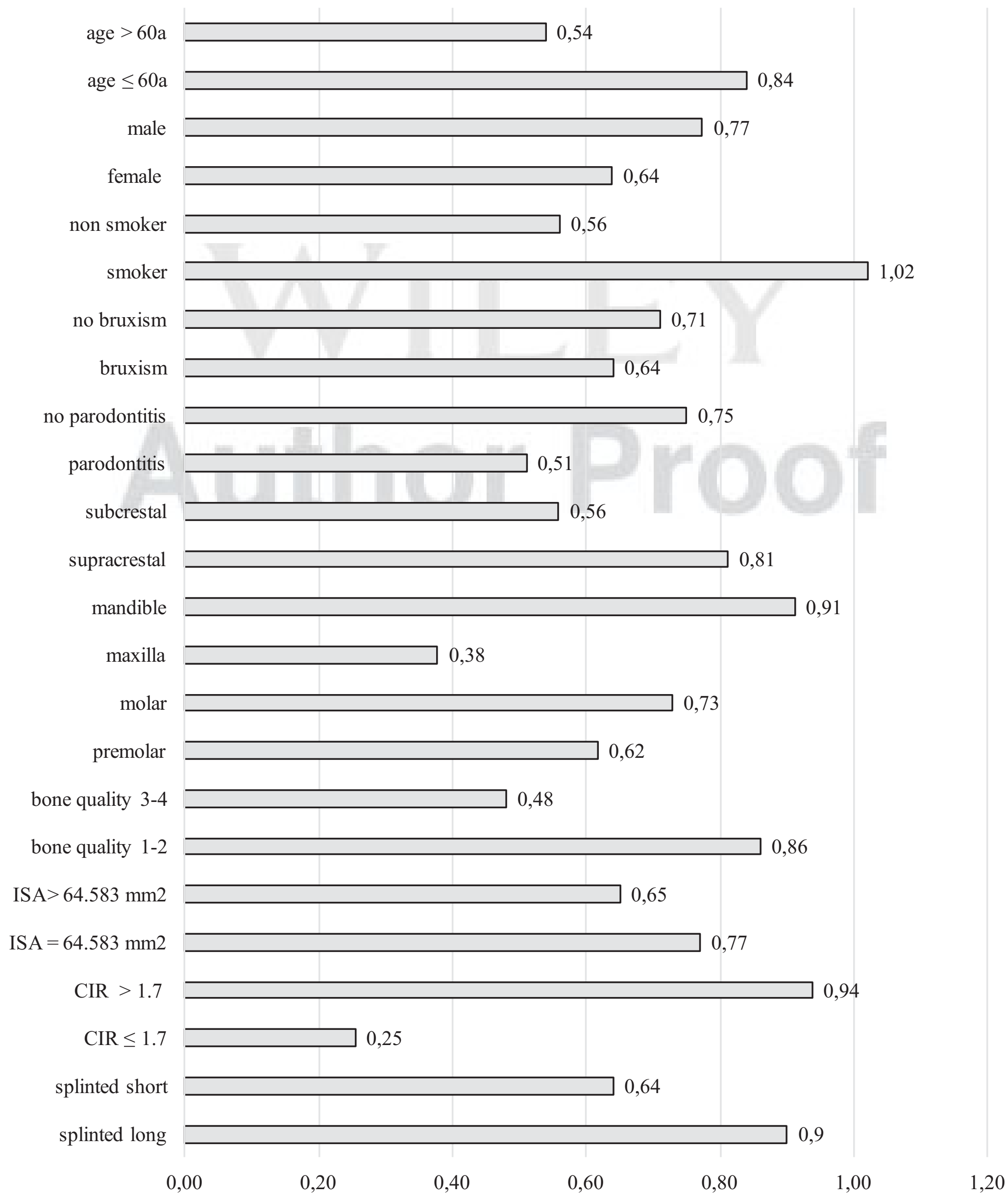

FIGURE 4 Mean values of MBL related to subgroups of patient, implant and prosthetic factors. ISA, implant surface area; splinted long, implants splinted onto longer ones; splinted short, implants splinted onto short ones

TABLE 4 Subgroup testing

Subgroup			*P*
Age > 60a		Age ≤ 60a	0.322
Male		Female	0.784
Smoker		Nonsmoker	0.025*
Bruxism		No bruxism	0.220
Parodontitis	vs	No parodontits	0.543
Supracrestal		Subcrestal	0.046*
Maxilla		Mandible	0.008*
Molar versus premolar		Premolar	0.632
Bone quality 1–2		Bone quality 3–4	0,058
ISA = 64 583 mm^2		ISA > 64,583 mm^2	0.954
CIR ≤ 1.7		CIR > 1.7	<0.0001*

subsequent years.[32] Thus, a MBL of 0.71 mm and a survival rate of 97.3% is considered to be satisfactory and comparable to other studies also investigating short dental implants[9,12,33–36] (Table 5). Two implants in the posterior mandibular region of one patient had to be explanted after 2 months following insertion due to implant loosening as a consequence of failed osseointegration. According to Simons et al. a decrease arterial supply of the mandible due to tooth loss, biological changes during aging and surgical trauma concomitant with implant insertion results in ischemic conditions that seriously inhibit the process of osseointegration.[31,37] Consequently, complications and early implant failures are commonly described in this poor vascularized region.[37,38]

According to the results of this study CIR has a high impact on early peri-implant bone loss as an increase of CIR is associated with higher MBL. However, studies exist that do not support these findings.[21,30,39–41] Garaicoa-Pazmino et al. state that within the range of 0.6-2.36 the higher the CIR, the less the peri-implant MBL.[41] In addition, it is reported that an increased CIR may not be a risk factor for dental implant failure under appropriate plaque control.[42] Based on finite element analysis CIR was identified to play a role in stress reduction, as an increased CIR resulted in higher stress concentrations around peri-implant bone.[15] Following these findings, from a biomechanical point of view increased MBL can be expected with higher CIRs, as mechanical overloading, as well as disuse, provokes peri-implant bone resorption.[26,27]

As clinical CIR is considered more relevant than anatomical CIR for biomechanical analyses only clinical CIR was calculated in the present study.[39,41] The clinical CIR is the radiologically measured ratio of the implant plus the crown length not surrounded by bone and the portion of the implant embedded into the alveolar bone.[21,41] Beside the clinical CIR, the anatomical CIR can be measured taking the implant shoulder as the boarder without considering adjacent bone levels.[21,39,41] In this study, according to Pommer et al. the sum of individual CIRs by the number of implants has been calculated in the situations of splinted crowns and used as the overall CIR.[43] The same method was used for ISA. This reduces the falsification of individual CIR and ISA as often

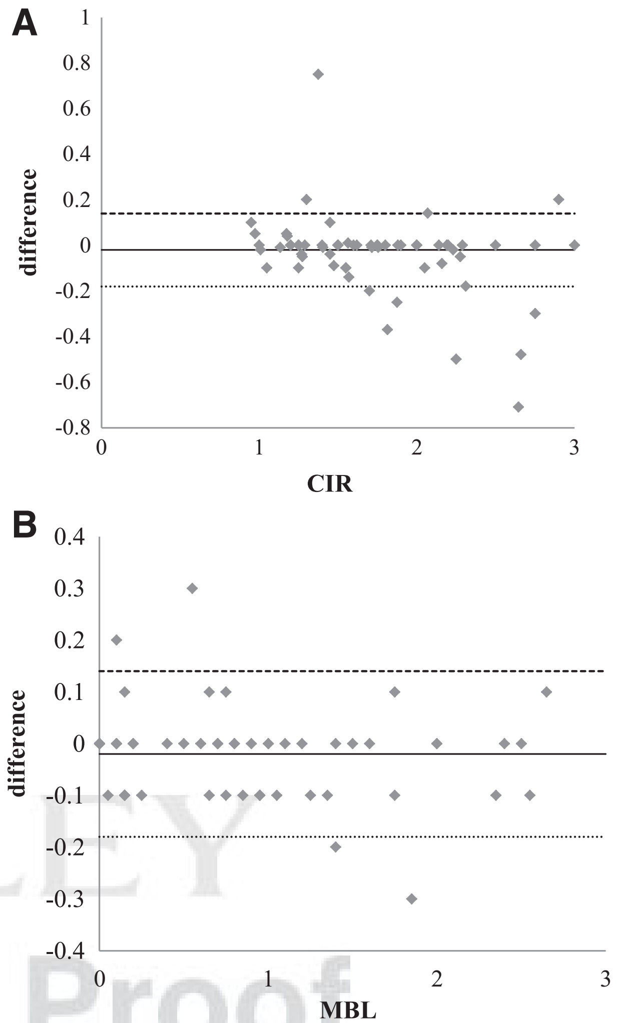

FIGURE 5 Interexaminer differences of MBL measurements and CIR calculations visualized by Bland-Altman plots. Dashed lines indicate 95% prediction intervals

various different CIRs and ISAs values are found within the same restoration and solitary validation is considered unrevealing.[43]

Results indicate significant higher MBL around implants of the mandible compared to those of the maxilla. According to Simons et al. a positive correlation between MBL and the proportion of cortical bone exists.[31] Significantly less resorption around implants inserted in sites with a higher proportion of cancellous bone (>60%) compared to implants placed in mandibles consisting of less than 30% cancellous bone, both after one year as well as after 3–4 years, occurred.[31] As the mandibular bone generally possesses a decreased cancellous proportion compared to maxillary bone,[44] these findings provide a reliable rationale for the increased MBL measured around mandibular implants in this study.[31,45] Additionally, the mean CIR in the lower jaw was higher compared to the maxilla. Thus, the increased resorption rate measured around mandibular implants reflect the influence of CIR on MBL.

Regarding the splinting of implants, MBL was not decreased when implants were splinted onto longer ones. However, authors support the opinion that splinting of implants lead to a better distribution of

TABLE 5 Overview and key findings of studies investigating splinted or nonsplinted short implants

Study	Number of implants	Implant dimensions (mm)	Follow-up (months)	Survival rate	Mean MBL (mm)
Single crowns					
Villarinho et al. (2017)	46	6.0 × 4.1	45	91.3%	0.3
Rossi et al. (2015)	40	6.0 × 4.1 and 4.8	60	95.0%	0.7
Bechara et al. (2016)	45	6.0 × 6.0–8.0	36	100.0%	0.3
Splinted crowns					
Rossi et al. (2017)	40	6.0 × 4.1 and 4.8	60	90.0%	0.30
Present study	74	6.5 × 4.0	12	97.3%	0.71
Fixed full-arch prosthesis					
Seemann et al. (2017)	40	4.0 × 5.0	19.5	97.3%	0.15
Calvo-Guirado et al. (2016)	40	4.0 × 4.1	12	97.5%	0.58

occlusal forces and the risk of implant overloading is reduced.[46–50] In Table 5, studies investigating either fixed full-arch prosthesis, splinted crowns, or single crowns are listed.[9,12,33–36] Comparison of survival rates and amount of marginal bone loss among groups are highlighted.

In smokers, a significant higher MBL compared to non-smokers was recorded. This supports the findings of several studies that prove the association between smoking and MBL.[51,52] Although bruxism and periodontitis are also named risk factors for increased MBL, these parameters could not be associated with enhanced peri-implant bone loss within this study.[53,54]

This multifactorial analysis aimed to include the most important parameters from implant surgery to follow up. Bone levels were measured directly after prosthetic restorations were applied and one year after implant loading. This procedure ensures to measure only bone resorption taking place during implant loading. Long-term implant stability and therefore also implant survival highly depends on the persistence of the marginal bone levels.[25,55] During the first year of loading the highest rate of bone resorption occurs, thus reports on MBL should especially include the first year.[31,55–59] As the study was carried out as an univariate analysis of parameters, results have to be evaluated subject to potential confounders including domestic oral hygiene respectively plaque control. This study is the first prospective evaluation of MBL and potential influencing factors of short implant. Nevertheless, the study is limited by the follow up period as well as by the non-cohort study design. More prospective cohort studies, investigating peri-implant bone loss of short implants according to patient-, implant-, and prosthetic-related parameters are needed to prove these findings.

7 | CONCLUSION

Within the limitations of this study, it can be concluded that, as implants shorter than 10 mm have CIRs of $\geq$1.6 in average, they carry the potential of increased marginal bone loss.[60,61] A CIR of 1.7 can be considered as a benchmark for clinicians and to avoid increased early marginal bone loss it is suggested not to be exceeded.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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